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John D. Barrow

THEORIES OF EVERYTHING:
The Quest
For Ultimate Explanation
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John Barrow is a professor of Astronomy and in his new book, *Theories of Everything*, he evaluates the claims widely made during the past few years that recent progress in theoretical physics will shortly bring the subject to an end, with the final discovery of a Theory of Everything, or TOE as it is now commonly referred to. Candidate TOEs have been around for a very long time. Thales' famous dictum "Everything is made of water" is, I suppose, the first example of a TOE designed to explain everything according to a rational principle, rather than invoking the supernatural agencies of Gods, spirits and demons. Another famous example was that of Roger Boscovich in the eighteenth century, who proposed a unified force law to explain all known physical effects. By the end of the nineteenth century the physical sciences had progressed to such an extent that scientists like Lord Kelvin believed that all that remained to be done was to measure physical constants to the next decimal place in accuracy. As Barrow notes, even the Prussian Patent Office was closed down in the belief that there were no more inventions to be made.

Ironic, then that, at the beginning of the twentieth century, at another Patent Office in Berne, a junior clerk by the name of Albert Einstein was to launch theoretical physics in totally new directions after the development of Einstein's special and general theories of relativity, and the introduction of the new quantum mechanics in the 1920s, Max Born was again to remark "Physics will be over in six months". But with new and quite unsuspected discoveries in nuclear physics everything started to look messy and complicated again, and it is only quite recently that physicists have had the temerity to claim that the Holy Grail of a final TOE, which has so far eluded them, is now finally within their grasp.

What has prompted this new optimism, and is it justified? These are the issues addressed in *Theories of Everything*. First, let me say that Barrow is well aware of the dangers of scientism. As he puts it, a TOE could not be expected to explain the significance of the works of Shakespeare, the Taj Mahal, or the Mona Lisa. Furthermore, while recognizing the importance of socio-cultural factors in the development of science, he firmly resists the modern fashion of seeing it as nothing more than a social construction. In largely non-technical terms Barrow succeeds in conveying clearly and accurately the flavour of what has been going on recently in theoretical physics.

He presents the task of the theoretician as essentially one of compression of the enormous diversity of natural phenomena in terms of an interlocking set of simple mathematical principles or axioms. There are some empirical data which cannot be compressed, the so-called random sequences which there is no shorter way of representing than by simply listing the sequence itself; but if Nature were completely random, there would be no possible compression, and science would consist, in Barrow's phrase, of mindless stamp-collecting – the indiscriminate accumulation of every available fact.

The amazing discovery about the universe is that apparently it exhibits an orderliness which allows the compressions we call theoretical physics. But there are two limitations to this simple picture. First, it is widely held that randomness is an essential aspect of fundamental processes in physics, and that what the mathematical compressions may represent for us are only the statistical regularities exhibited by random sequences, rather than, *per impossible*, the individual terms in these sequences. Second, we can only know these statistical regularities and how they change in time, if we have appropriate information about the initial conditions which start the physical system off; but in the context of an ultimate TOE this would mean knowing the initial state of the whole universe. One of the most exciting ideas expounded in Stephen Hawking's *A Brief History of Time* was that in a precise mathematical sense the universe did not have an origin *in* time, as we understand that term, but that time itself evolved out of an essentially timeless state of Being. Barrow explains all these difficult ideas, and much more besides, in a very direct and straightforward style, not attempting to bamboozle us with meaningless metaphors, but accurately to convey the sense of what are essentially mathematical concepts, and not at all underestimating the speculative nature of many recent proposals, such as Hawking's "no-boundary" universe.

Barrow emphasizes the importance of symmetry principles in developing the new unified TOES. These tell us in what respects the transformations of physical systems leave them unchanged, ie, they specify what mathematicians call the invariants of a transformation group. Specifying the symmetries in this general sense constrains the associated mathematical principles governing the systems behaviour. But there is a basic snag in using symmetries to explain the behaviour of specific physical systems, since that behaviour may typically fail to manifest the symmetry governing the behaviour of physical systems in general, ie, aggregated from all possible specific systems. This is the phenomenon of "symmetry-breaking", which is responsible for the fact that the behaviour of a specific physical system may appear much more complicated than the underlying symmetrical physical laws. It is generally agreed that the present state of the universe is the outcome of a series of randomly occurring symmetry-breakings, which means that the TOE cannot itself predict many of the universe's essential features as we currently observe it - a very important limitation on what TOEs can be expected to deliver, even in principle.

At this point there enters the important Anthropic Principle, which holds that the universe we observe, containing the values we give to various fundamental constants, must be at any rate consistent with the fact that complex organisms such as ourselves have been able to develop and make these very observations. Taking account of the random element in the development of our universe this may result in a very biased selection from all possible universes, whose features may depart radically from the "most probable" features pertaining across all universes. This whole matter is dealt with very sensibly by Barrow, who in no sense claims that the Anthropic Principle shows that the universe we inhabit was created *for* us, in some religious or teleological sense.

But the development of highly organized and very complex physical systems such as the human brain again shows the shortcomings of the TOE approach. To discuss in a scientific fashion the details of human behaviour the last thing one wants to do is to write down and solve exactly the N-particle Schrödinger equation, or its more modern substitutes, for unimaginably large values of N. This is in no way to claim that human brains do not obey general physical principles - there is no argument here for a neo-vitalism - buts, as Barrow stresses, the focus of interest becomes quite different. Invariance, which is so crucial a notion in elementary particle physics, is no longer relevant, the particular replaces the general, *specific* events and the relation between them in time are now the dominant consideration, while general principles governing the development of organization may still wait to be discovered.

In a final chapter entitled "Is pi really in the sky?", Barrow turns to the question of understanding the nature of pure mathematics and its relation to a possible TOE. He draws a sharp distinction between those parts of mathematics which consist of applying a mechanical rule - what mathematicians call an algorithm - in an essentially mindless way, and those parts which go beyond mere computation and provide the genuinely creative side of mathematics. Barrow appeals to the famous Gödel result showing the ineliminable incompleteness of many formalized mathematical systems, in which a mechanical churning-out of theorems may never reveal the truth of certain mathematical statements. Here he sees the source of what he calls "prospective" features of the universe which cannot be recognized or even generated in a finite sequence of logical steps. As he puts it, "The prospective features of the world cannot be trammelled within any logical Theory of Everything".

John Barrow provides a very honest and valuable guide to all these issues, and is rapidly establishing a reputation for himself as the heir of Jeans and Eddington in bridging the gap between the research frontiers of theoretical physics and the aspirations of the man on the clapham omnibus to understand what is going on.